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GUIDELINES FOR ESTIMATING THE SURVIVAL OF FIRE-DAMAGED TREES IN CALIFORNIA

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Survival of conifers after fire damage depends on time of year when the fire occurred, the growth vigor of the damaged tree before the fire, and degree of damage to cambium, foliage, and twigs. Guides by tree species or species groups are given for judging survival chances of individual damaged trees.

GUIDELINES FOR ESTIMATING THE SURVIVAL OF FIRE-DAMAGED TREES IN CALIFORNIA[1/]

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1/ This paper revises and replaces "Preliminary guidelines for estimating the survival of fire-damaged trees," Research Note No. 98, October 4, 1955.

GUIDELINES FOR ESTIMATING THE SURVIVAL OF FIRE-DAMAGED TREES IN CALIFORNIA

By Willis W. Wagener

When virgin timber was plentiful in the West, stands swept by fire were considered lost. As old-growth was harvested and timber values increased, salvage logging after fires gradually became a common practice, and establishment of a new forest by planting or seeding burns received increasing attention. Today, rehabilitation of a burn ranks with or above salvage in importance.

In rehabilitating burns, foresters recognize the need to take advantage of the natural capacity of trees to recover from fire damage. Where few trees escape heavy damage and planting is scheduled, clear cutting in salvage operations is often advisable. Clear cutting permits more efficient planting and more thorough site preparation. In large burns planting cannot be scheduled immediately, and leaving trees that would survive offers a chance for natural regeneration and gains in time, quality, and seed source. To capitalize on this chance, foresters need to understand a tree's survival potentials after fire and how to judge them.

In 1939, following early work by forest entomologists (Miller and Patterson, 1927; Miller, 1929; Salman, 1934; Miller and Keen, 1960), the Office of Forest Pathology 2/ began a study in California of the survival of fire-damaged ponderosa and Jeffrey pines. The study was originally confined to these two pine species because of their high intrinsic value and the prevalence of misconceptions regarding their survival chances following fire. Later it was extended to other conifers.

Sample damaged trees were selected on fresh burns and their condition recorded. Reexaminations were made annually until mortality had returned to normal, usually within 3 to 4 years. Observations on 30 burns located on 12 national forests in California and in Yosemite National Park provide the basis for generalizations presented here as guidelines. Part of what follows is in the nature of background to aid in the understanding of the criteria for survival.

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Influence of Fire Date on Survival

Conifers are most susceptible to fire damage early in the growing season, when length growth of the main stem and of twigs is active. This growth is chiefly from food reserves stored during the previous season. Such reserves are at their lowest during the period of length growth. Also, during this time, growing points are tender and easily killed by heat. The length-growth period varies in timing with elevation, species, and duration of snow cover but in California is likely to be at a maximum in June (Fowells, 1941).

After length growth ceases, the terminal buds form and, in pine species such as ponderosa and Jeffrey, become well protected by scales by the end of summer. In this stage the buds are able to withstand considerable heat without serious damage. Diameter growth on the tree, which proceeds largely from food currently elaborated by the foliage, stops in late summer, but food reserves continue to accumulate during the balance of the season. Thus the later the fire the better the tree is prepared to withstand fire damage. In an early-season fire, a conifer is highly vulnerable to heat damage at a time when the tree must retain sufficient green foliage to carry it through the remaining part of the growing season and provide some food reserves for the next year.

The time of year at which the fire occurs also affects subsequent bark beetle activity, which can materially influence survival. According to Miller and Keen (1960) "if a fire occurs in the late spring or early summer, some concentration of infestations within a burn develops by late fall of the same year." After late summer or fall fires, however, "beetles do not concentrate within a burn until the season following the fire." Our records support these conclusions. Any scattered attacks that may occur after a late-season fire are likely to be confined to mortally-damaged trees with mostly live cambium but with little prospect for survival.

Survival in Relation to Growth Rate and Site

The survival chances of a scorched conifer are strongly influenced by the condition of the tree before the fire. Young, fast-growing trees on good sites have the best chance, and old, overmature veterans on poor sites the poorest chance to recover from fire damage. Fire-injured trees of any age that were making slow growth before a fire will have a low recovery potential afterward. On the other hand, vigorous young ponderosa pines on good sites occasionally survive 100 percent heat-killing of foliage in a late-season fire if most of the buds and twigs remain alive. Even on good sites, old, overmature, slow-growing trees are poor risks to live after a fire if damage is at all severe.

Survival in Relation to Tree Damage

Bud and twig kill, foliage kill, and bark and cambium kill, all need to be considered in judging whether a tree is likely to live after a fire injury. In past marking on burns, the tendency has been to base judgments too much on the amount of green foliage remaining, without sufficient attention to other factors influencing survival. Actually, as Miller (1929) has pointed out, it is the total growth capacity of the tree for the year or two after a fire that largely determines a scorched tree's fate.

Crown Damage

Except for very early-season fires, the crown condition the year following the fire is more important for survival than the condition shortly after the blaze. In ponderosa and Jeffrey pines extensive heat-killing of foliage may sometimes occur with only light damage to buds and twigs. During the succeeding months most of the dead foliage will be shed from twigs that are still alive; a new crop of needles will be put out from them the next growing season. Thus the amount of green crown the year after a fire may be much greater than that a month after in these pines. The new foliage on a defoliated part of the crown is not quite the equivalent of uninjured crown because it bears only current year's needles, but these help greatly in keeping the tree alive until a normal needle complement is attained.

In species with slender twigs and small terminal buds, as in sugar pine, Douglas-fir, and the true firs, or in those without definite terminal buds, as in incense-cedar and giant sequoia, foliage kill and bud and twig kill from fire are not greatly different in amount. Thus, the amount of green foliage present in scorched crowns in these species shortly after a fire is reasonably close to the amount that will be present in the immediately following years.

Damage to Bark and Cambium

Miller (1929) and Salman (1934) each observed that pines with both heavy foliage scorching and moderate to severe cambium kill as a result of fire were more likely to die later from bark beetle attack than pines with only one of these types of injury. Where both types of injury are present, food materials available for repair of the damage are sometimes insufficient to be fully effective.

Conifer bark varies greatly between species in insulating capacity and in other characteristics that influence the protection afforded to the cambium against heat injury. Even in a single species, wide differences in bark thickness, depth of crevices, and size of bark ridges or plates influence the amount of stem damage. Damage is also influenced

by the amount and distribution of forest fuels—ground cover, litter, duff, and debris near or on the ground. Thus in uneven-aged stands of mixed species swept by fire, injury to the cambium is likely to show considerable variation in locations where tree killing is not complete.

Cambium killing that extends up the trunk for more than a few feet has a greater influence in reducing chances for survival than injury close to the ground. Inner bark injury from heat high on the stem where the bark is thin is particularly likely to result in later mortality. Injury of this character sometimes occurs adjacent to areas of localized crowning of the fire.

Sugar pine constitutes a special case. In proportion to diameter, sugar pine has thinner, denser bark, with poorer insulating capacity than the bark of associated conifers. During a fire, the burning of fuel accumulations at ground level often kills a ring of cambium only a few inches in height around part or much of the base of sugar pines, even where the bark shows only minor scorching on the surface above this level. Larger sugar pines can occasionally be found with inconsequential needle scorching and little blackening of the trunks but more than half girdled at ground level by a narrow band of killed cambium. To offset this greater susceptibility to basal cambium killing than in associated conifers, sugar pine withstands the effects of partial girdling much better than associated species.

Bark Beetles and Survival

Fire-damaged trees are weakened physiologically, and for two or more years are more attractive to bark beetles than normal trees (Miller and Keen, 1960). Trees with a good survival potential often adjoin others with little or no survival prospects but with enough green cambium and live twigs to attract bark beetles. If salvage logging in such situations is delayed too long, bark beetle broods emerging from heavily damaged trees will be likely to attack neighboring trees that would otherwise survive.

According to observations during the study, beetle attacks and spread are particularly likely in young-growth ponderosa pine stands swept by a relatively hot ground fire. Such stands yield little lumber of upper grades and loggers have the tendency to leave them until the last in salvage operations. By this time the bark beetle population often is high, and many trees that would otherwise have survived have been attacked and killed.

The remedy is obvious: logging should be adjusted to salvage such stands before beetle infestation has pyramided, preferably by at least midsummer of the year after the fire, taking out all infested trees in the process. Only in this way can the real survival potential of the stand be realized. There will also be less sapstain in the salvaged trees than when logging is delayed.

The pinkish or reddish pitch tubes of the red turpentine beetle, Dendroctonus valens Lec., were noted on the bases of 30 percent of the pines included in the study, mostly within a year after the fire. Where not numerous, the beetle work evidenced by their presence seemed to have no apparent effect on the survival of affected trees.

Seed Production from Damaged Trees

Attention should not be focused exclusively on salvage or survival in the marking of fire-scorched timber. A fresh burn provides an excellent seedbed and seed produced by scorched trees is sometimes highly important in regenerating a burn.

Before marking is started in parts of a burn where the fire has not crowned, the cone status on the pines should be investigated, particularly with respect to the juvenile cone crop that will mature the following year. Exceedingly good stands of seedlings sometimes result from these cones, even though the trees bearing them may not live beyond the second year after the fire. The prospects of a good seed crop will sometimes justify the temporary retention of trees that would otherwise be marked for initial salvage, or that would normally be cut under certain silvical concepts such as unit area control.

The production of a heavy cone crop draws on nutrients that would otherwise aid in recovery of the parent tree, and makes it more susceptible to subsequent loss than equally damaged trees without a cone crop. Thus trees with a heavy cone crop may die the second year after the fire. However, they can still be salvaged after the seed crop has been obtained.

Judging Fire Injury

In Crowns

Where the fire has crowned or has been so intense that no green foliage is left, marking offers no problem and can proceed at once. Salvage logging in such timber should start as soon as possible to avoid deterioration.

Where some green foliage is left and pines with relatively large buds and twigs, such as ponderosa and Jeffrey pines, are major stand components, marking should be delayed for two or more months if possible. It should not be done in the fall if the timber will not be logged until the next spring. By spring most of the scorched needles will be shed from twigs that are still alive but not from dead twigs. Thus live parts of the crown will appear thin in contrast to the dead parts, allowing the marker to tell easily how much live crown is present to produce green needles when growth starts. The amount of live crown present, as distinguished from green foliage, is the most important single factor in the survival of fire-scorched ponderosa and Jeffrey pines.

For preliminary estimates, or where prompt marking is unavoidable in parts of burns where killing is not complete, the following suggestions are offered:

(a) Mark or estimate only on clear days. Green parts of partially scorched foliage are extremely hard to see against a cloudy sky.

(b) Wherever possible, view crowns from the side on which the sun is shining and at right angles to the direction of run of the fire. The lee side of the crown usually is the least damaged.

(c) Use field glasses to check naked-eye impressions. Green needle bases that indicate that surrounding parts of the crown are still alive can often be seen with the aid of field glasses but are not distinguishable with the naked eye.

(d) Watch the position of foliage. Twigs bearing darkened needles that are "frozen" in position in the direction of run of the fire are certain to be dead. Heat-killed foliage on live twigs stands or hangs in a normal position. The presence of such foliage does not always signify live twigs, but it is a hopeful indication that they may be alive.

(e) Anticipate less difference between the percent of live crown and the percent of green foliage after a midseason than after a late-season fire.

In Bark and Cambium

Cambium injury is ordinarily heaviest on the lee side of the tree with respect to the direction of run of the fire and on the uphill side of trees located on slopes. Killed patches of cambium are usually widest just above ground level and taper upward.

The degree and location of bark charring provides some indication of where to look for cambium injury, but for each area the relationship should be checked by exploratory sampling through the bark with an axe. Enough trees should be sampled to provide for reasonably accurate judgments regarding cambium injury on the rest. In most species, killed inner bark or cambium is readily recognized by a change in color to some shade of brown or gray and by resin infiltration of the wood in the cambial region. In white and red fir, however, no appreciable color change accompanies injury to the inner bark and cambium, no resin infiltration is induced, and the limits of cambium killing are difficult to judge.

The most common form of injury to cambium or inner bark is narrow strip killing or browning underneath deep bark crevices on the lee side of the tree. Ordinarily it has little influence on survival.

Basal patch killing of cambium involving less than one-sixth of the circumference of the tree at the ground and extending up for not more than a foot is also usually of minor significance for survival. A third type of cambium injury commonly found on burns is the death of thinly protected callus tissue around the borders of old fire wounds or cat-faces. This killing likewise seems not to have much influence on the survival chances of a tree unless it extends beyond the callus zone and forms a broad band of killed cambium.

Scattered resin drops over the charred bark of lower trunks are usually not significant as indicators of cambium injury. Scattered drops come chiefly from dead branch stubs or the bases of lower branches and not from the bark of the trunk itself. Concentrated resin flow from specific areas of bark or exposed wood, on the other hand, does indicate killed cambium underneath. The flow usually issues from calluses around previous fire wounds, from old dwarfmistletoe cankers on the trunk, or from irregularities in normal trunk contours from other causes. It is also common where large chunks of fallen logs have burned close to the bases of trees.

Survival Criteria

Most timber fires in California occur after the first of August, most sites burned over are relatively good, and the trees with the best chance for survival are those with good growth vigor before the fire. Marking criteria for trees falling within these specifications are given in table 1, together with modifications for certain other conditions. Trees not meeting the criteria, such as pines with less than 50 percent of live crown, slow-growing trees, or those with severe cambium injury, should ordinarily be cut unless reserved only temporarily.

No criteria are given for early-season fires because of lack of data; no early-season fires were included in the study. From general considerations, however, it is believed that reserved trees from an early-season fire should have 35 percent or more of green foliage.

Variable percentage criteria are given for midseason (July) fires to permit adjustment to the conditions on a particular burn. The growth and developmental status of a tree changes rapidly during July, seasons differ in being late or early, and trees at low elevations start growth much earlier than those at higher elevations (Fowells, 1941). Accordingly, no one criterion is likely to fit all July burns. In general, trees on an early July burn require more green foliage for survival than trees on a late July burn.

The studies did not include any areas under severe drought stress so they provided no information on how drought might affect fire survival. Chances are, however, that no more green crown would be

needed for survival under drought conditions than when moisture was normal. Fires reduce the competition for soil moisture and by killing some foliage, reduce moisture needs of individual trees. Thus the moisture supply to the living parts of a tree after a fire in a drought area may actually be better than before the fire.

Definition of Terms

Fire period:

Early season—Fires occurring before July 1.
Midseason—Fires occurring during July.
Late season—Fires occurring after August 1.

Cambium injury:

Light—Confined to injuries characterized in the section on "Judging Fire Injury" as having little effect on survival.

Moderate—On species other than sugar pine, cambium killing involving less than 25 percent of the circumference and not extending above stump height, except for narrow strip kill under a few bark crevices. On sugar pine moderate injury includes basal cambium killing at ground level involving not more than 60 percent of the circumference.

Severe—Cambium injury in excess of that described under the above classes.

Live crown:

The proportion of the original live crown in which twigs and buds are still alive after the fire, including parts bearing green or partly green foliage. Often irregularly dispersed. Estimated to the nearest 5 percent.

Green foliage:

The proportion of green needles present after the fire without respect to location within the former crown, compared with the green needle complement before the fire. Includes the green part of partly-scorched needles. Estimated in percent as closely as possible.

Table 1. —Criteria for survival marking of fire-scorched timber in California

Influencing factors	Minimum criteria for survival of—					
	Ponderosa pine Jeffrey pine			Sugar pine Douglas-fir [1] White fir	Red fir Incense-cedar Giant sequoia	
	Cambium injury	Live crown	Green foliage	Cambium injury [2]	Live crown	Green foliage
		---Percent---			---Percent---	
General specifications						
Fire period—late season Site quality—above average Growth vigor of tree before fire—good	None or light	50 or more	10 or more [3]	None to moderate	45 or more	35 or more
Modifications						
In cambium injury—general specifications as above	Moderate	50 or more	20 or more	--	--	--
In site—below average, Sierra East Side and West Side, other general specifications unchanged	None or light	50 or more	15 or more	None to moderate	50 or more	40 or more
In fire period—midseason other general specifications unchanged	None or light	50 or more	15 to 25 or more	None to moderate	50 or more	40 to 50 or more
In growth vigor—crown small, vigor moderate, other general specifications unchanged	None or light	60 or more	15 or more	None to moderate	55 or more	45 or more

1/ Does not include bigcone Douglas-fir. In this species the percent of live crown is not readily determinable; green foliage should be 20 percent or more.

2/ In sugar pine, includes up to 60 percent basal girdling.

3/ Not an actual green foliage minimum for survival. Seventy percent of the pines in the study with 50 percent or more of live crown but with less than 10 percent of green foliage survived.

Estimating, Marking, and Logging on Burns

On parts of burns where the fire did not crown and killing is not complete, early estimates of loss or salvage should be applied with ample provision for later adjustment after survival prospects have become more definite.

Marking in such timber is best done with a two-man crew, one to examine crowns from a distance and the other to appraise for cambium kill and apply the marking symbols.

To obtain maximum salvage, survival, and seed crops on burns, two-stage logging is advisable. The survival of seriously damaged trees is in part a matter of chance, depending on weather conditions, bark beetle activity, and actual bark and cambium injury as compared with the estimated injury. The first round of logging should be confined to pines completely killed or with little chance for survival and in which sapstain is likely to affect the value of the product. Associated species such as the firs and incense-cedar, in which sapstain is ordinarily not a major consideration, should be left for a second round. At this time the logger can also take out any dying or beetle-attacked pines that have shown up among those reserved in the first round.

Two-stage logging has several advantages. It permits a more rapid coverage of a burn than would be possible if everything were taken on a single round. It reduces the chances for deterioration in the part of the timber most subject to degrade from stain and borers. It also tends to hold down bark beetle activity.

Discussion

From what has been presented, it should be clear that handling burns for maximum survival and natural seeding requires flexibility in practice and thinking. One general practice has been to mark an entire burn as soon and as rapidly as possible, even though the salvage logging may span many months. If tree killing was complete, this practice has much to commend it. In those parts of the burn where killing is not complete, it practically guarantees poor marking for survival. Incomplete kill is most likely in backfired areas or where the fire burned downhill at night. If marking in such areas is delayed until the timber is actually needed in logging, a very much better job of saving trees with a good survival potential is possible.

Saved trees may permit more effective use of limited planting funds. Improved methods have led to good planting success in California in recent years, but planting is still expensive. It may be

necessary to concentrate planting on ground where kill has been complete and there is little possibility of natural reseeding. The temporary retention of living trees to mature a seed crop and the protection during logging of seedlings established on a burn the first season after a fire (Roy, 1956) are measures which deserve consideration.

Another common practice has been to leave the plan of logging in a salvage operation entirely up to the logger, who usually starts at the most accessible part of the burn and works through. On small burns, where the entire salvage job will be completed in two or three months, this method of operation is as good as any. On larger burns, however, the plan of logging needs to be adjusted to the condition of the timber if the most is to be accomplished with the least loss. On very large burns, especially under mixed ownerships, the prospects for adjusting logging to reduce losses are usually less favorable than on smaller burns, but this does not mean that in such cases nothing should be attempted. Cooperation can often be obtained if the people concerned understand the objective: to save for the future all the trees that can be saved.

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